Technical sciences

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INNOVATIVE COMPOSITE MATERIALS BASED ON GRAPHITE IN SMART HOME PARTS

Summary. *Innovative Composite materials based on graphite in parts and structures of a smart home, practically competing with other latest developments in this area*

Introduction. In the most efficient electrochemical reactors developed within various programs aimed at creating water purification and regeneration systems for technological water in smart home infrastructures without the use of chemical reagents, fabrics made from carbon and carbon composites provide virtually all the advantages over other alternative technologies.

The names of these fabrics are Etan and Khortytsia, and they are an innovative product of the company UKRUGLEKOMPOZIT from the city of Zaporizhzhia, Ukraine. Considering the unusual effect that the electrochemical reactor acquires when these composite fabrics are used as electrodes and electrode contact systems, it can be preliminarily concluded that these materials may not have been sufficiently studied and qualified for compliance with the criteria for nanosized composite materials at the time.

Materials and methods. These materials have been in use for over 10 years, and their increasingly interesting properties and qualities continue to be discovered, while more scientific publications are appearing with reports on the development of carbon composite materials and their modifications.

Purpose. Practical experience in non-industrial fields shows that there is a huge potential for the targeted and efficient use of such materials, such as in gilding techniques during restoration.

The application of these materials helps eliminate many outdated problems, in particular, issues related to edge effects in the electrode cells of electrochemical reactors. Given the exceptional effect from the complex application of these materials, scientists and researchers continue their search.

Key words: Composite material, Graphite-based composite materials, Laws of quantum mechanics, Graphene, Atoms with double bonds, Atoms with triple bonds, Miniature transistors, Arrangement of carbon atoms, Development of composite materials, Chemically active composite, Graphene films, Hydrogen energy, Electrochemical water treatment.

Introduction. A recent message reported that physicists have discovered unusual electrical properties in graphine, a cousin of graphene (also a two-dimensional allotrope of carbon), which could be used for the development of transistors based on this material.

In graphene, carbon atoms are arranged in a single plane, forming a hexagonal lattice. However, unlike graphene, graphine features atoms with double and triple bonds, resulting in a structure that deviates from the regular hexagonal grid. As a consequence, there are many different structures of graphine. In the study, the so-called 6,6,12-graphine was examined, which consists of two types of hexagons: a regular one with sides of length 1, and an irregular one with sides of lengths 1 and 3.

Using density functional theory—the primary method for calculating the electronic structure of molecules and condensed matter, based on the laws of quantum mechanics—the researchers concluded that the electrical conductivity of this material depends on the direction. According to the scientists, this property could be harnessed to create transistors.

As of now, graphine (not 6,6,12-graphine) has been synthesized only once.

According to chemists, small fragments of graphine can be synthesized in laboratory conditions, but complete sheets, which demonstrate its unusual properties, have not yet been successfully produced.

Andrei Geim, who won the Nobel Prize in 2010 for the discovery of graphene, stated in an interview that "graphine is already a very interesting material, and the new results make it even more fascinating." He also hopes that the development of practical technologies to produce this material will not take 60 years (referring to the history of graphene, which was theoretically predicted long before it was actually synthesized).

In early 2009, scientists succeeded in producing **graphane**. By treating graphene with gaseous hydrogen in the presence of an electric current, hydrogen atoms attached themselves to the carbon atoms alternately, one from the top of the "sheet" and the other from the bottom, slightly deforming the flat structure of the original material. More details about this research: an international group of researchers managed to create a new material by combining graphene and hydrogen.

This new discovery may have applications in electronics and could also help advance hydrogen energy technologies.

It has long been known to scientists that graphene is chemically active (in contrast to its relative, graphite). To produce graphane, researchers placed graphene in gaseous hydrogen and passed electric current through the gas. As a result, the hydrogen molecules split into atoms that bonded to the original material.

To recall, graphene is a "sheet" made up of a single layer of carbon atoms arranged at the vertices of a two-dimensional hexagonal (i.e., each unit cell of the grid is a hexagon) lattice. The hydrogen atoms attach to the carbon atoms alternately: one on top of the "sheet," the other underneath, slightly distorting the flat structure of the original material.

The theoretical existence of graphane was predicted by a group of American scientists in 2006 based on computer simulations. Unlike graphene, which is an electrical conductor, graphane is a **dielectric**. According to the researchers, this property of the new material could potentially be used in the production of ultra-miniature transistors.

The addition of hydrogen atoms to graphene can solve one of the major challenges in the development of graphene-based electronics: the difficulty of creating conductive circuits. By adding hydrogen, regions of **graphane** can be formed on graphene. These dielectric regions can be used to divide the original material sheet into multiple conductive strips. This approach offers a new way to manipulate the material's properties.

Previously, one solution proposed by the same group of researchers to create conductive circuits was to physically cut graphene into strips several nanometers thick and then glue these strips together to form the circuits.

In addition, this new material could find applications in **hydrogen energy**. Specifically, an international group of researchers found that heating graphane leads to the release of atomic hydrogen.

This is significant because one of the main challenges in hydrogen energy is developing effective methods for hydrogen storage. One of the most promising research directions is creating materials capable of storing hydrogen in a bound state, such as in the form of graphane.

Physicists have also theorized that **doped graphane** could transition into a **superconducting state** at relatively high temperatures.

In their study, the researchers used computer modeling to simulate the behavior of doped graphane, where impurities were added in a specific manner to modify the magnetic and electrical properties of the material. They found that this material could become superconductive at a temperature of 90 kelvins (-183°C).

According to the physicists, one reason for superconductivity at such a high temperature is the "almost two-dimensional" structure of graphane. This material is derived from graphene by adding hydrogen atoms that alternate between attaching to the top and bottom of the graphene sheet, slightly distorting its flat structure. Additionally, the strong bonds between carbon atoms also play a significant role.

Moreover, the conditions in graphane, as theorized by the physicists, could be observed in **doped diamond nanosticks**, which are relatively easy to produce. This could open up new possibilities for both advanced electronics and hydrogen storage technologies.

The main obstacle to the wider use of superconductors is the need to cool them to ultra-low temperatures. If the predictions of physicists are correct, a **graphane-based superconductor** would only require a nitrogen-cooled refrigerator to function, significantly simplifying its application compared to traditional superconductors.

Currently, the process of producing **graphene films** is quite complex. At temperatures around 1000°C, carbon-containing materials evaporate, and the resulting vapor condenses onto special substrates. After the film is formed, it must be transferred to the "working" surface.

In a new study, scientists proposed a different method. In the first step, the surface is covered with a thin layer of nickel. Then, a paste containing graphite is applied on top of this nickel film. The resulting "sandwich" is dried, during which some of the carbon atoms penetrate through natural channels under the nickel layer, forming a one-atom-thick layer of graphene beneath it. The upper layers are then chemically removed.

This method could also be applied to unusual processes, such as **gold-leafing** during restoration work, where the durability of the coating is critical. In such cases, the coating is applied in several steps, with the first step being the creation of a primary layer with a high degree of uniformity.

This new method is simpler than previous ones in several ways. It doesn't require expensive or difficult-to-obtain single-crystal substrates—films can be formed on a variety of surfaces. In the study, the scientists tested their method on glass, plastic, silicon substrates, and others. By analogy, this could even extend to wood, such as for painting frames in restoration work.

This also means that the film can be created directly on the working surface, such as for electronic circuits. Furthermore, the new method only requires drying at temperatures between 25 and 160°C, which significantly simplifies the setup for graphene production and reduces its potential cost.

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In the context of the research mentioned above, scientists studied **bilayer graphene**, a two-dimensional carbon layer that is one atom thick, placed on top of another such layer. Despite the fact that the layers are spatially very close, they are isolated from each other (sometimes this structure is referred to as a "double layer," but without isolation – terminology is not fully established).

Now, researchers have successfully created a bilayer graphene structure that is covered on both sides with a layer of **boron nitride**. It turns out that such a system possesses a number of interesting properties. For example, it was discovered that if one of the layers accumulates enough charge carriers, the second layer stops conducting electricity. "This is the first case where a defect-free graphene sheet has been turned into an insulator".

These materials have the ability to "cleverly" change the paths of electromagnetic waves, leading to unusual optical effects, such as **invisibility**. If an object is placed near a **metamaterial**, the observer is tricked into perceiving the object as invisible because the waves reflected by it become "entangled" within the metamaterial and fail to reach the observer's eyes or the instrument's detectors.

Graphene is an allotrope of carbon consisting of a single layer of carbon atoms, one atom thick. It possesses a number of unique properties, such as exhibiting the highest electron mobility among all known materials. The **electrical conductivity of graphene** can be easily altered by changing the distance between the grounding plate and the graphene layer. This allows for the creation of zones with varying conductivity within a single graphene layer.

Electromagnetic waves propagate differently through layers with varying conductivity. By strategically arranging these zones, scientists can control the pathways of electromagnetic waves. This ability to manipulate wave propagation is crucial for technologies such as **smart home systems**, where precise control over electronic and optical signals is often required.

In one experiment, the researchers placed a pair of electrodes connected by a strip of graphene into a copper chloride solution at room temperature. A few of these batteries were enough to produce... [The sentence appears to be unfinished here].

Such research is particularly important for advancements in electronics, optical technologies, and the development of smart systems, where efficient and controlled electromagnetic wave manipulation can enable new, highly efficient devices.

A voltage of 2 volts, which was sufficient to light a small LED, was applied in one experiment with graphene-based batteries. The scientists explain the principle behind their battery as follows: during thermal motion, ions in the solution strike the graphene strip, knocking out an electron. This electron has two options: it can either move into the solution or go to the electrode. Since the electron mobility in graphene is much higher than in the solution, it chooses the second option. The researchers found that increasing the temperature enhances the battery's performance.

When reading about these and many other studies in this field, it becomes evident that such practical, real-world results – achieved through the use of carbon composite materials that were created at least 15 years ago – remain unnoticed and have not been deeply explored in the context of smart home infrastructure and ecosystem technologies.

Considering the advances in the production and application of **carbon-carbon composites**, it is clear that these materials have numerous potential applications, even in more conservative areas such as art restoration, where quality and durability are the key criteria for evaluating effectiveness.

The author of this publication believes that a series of practical experiments with **carbon-carbon composites**, such as carbon-carbon fabrics and carbon-carbon foams, is necessary. Such experiments could theoretically lead to a significant leap in the quality of smart home technologies.

For example, these materials and composites are already being applied in **electrochemical water treatment technologies** as part of the infrastructure of smart homes. Here's a brief overview of the potential applications of this technology.

The proposed technology involves an electrochemical process that affects water or aqueous solutions as they pass through an electrode volume, which is connected to a direct current power source and separated by a neutral membrane.

The contacts that supply the electrical potential to the electrode volume are made of non-metallic, chemically resistant materials and are permeable throughout their entire volume to water and aqueous solutions. The electrodes themselves are permeable to water and aqueous solutions throughout their entire volume and are made from non-metallic, chemically resistant materials, compatible with the material of the electrical contacts.

The water or aqueous solution is processed as it passes through the electrode volume, with the liquid flowing through the electrode volume under the influence of gravity in a directed upward flow. The electrodes are positioned vertically, and the liquid enters the internal electrode volume at the bottom and exits from the top.

The time the liquid spends in the internal electrode volume is the time during which the liquid is impacted, and the duration of this impact determines the level and depth of the effects on the working characteristics and parameters of the treated water or solution.

The device for this type of water and aqueous solution processing is an electrode cell with fluid input and output devices, connected to a source of electric potential. Since this technology is intended for local use, the expected sizes and output of the installation are modest. The primary distinguishing parameter of these installations is their productivity, which ranges from 50 to 250 liters per hour.

The installations are versatile and can produce the following types of specially treated water:

- Water with increased acidity.
- Water with decreased acidity.
- Alkaline water for use in various medical technologies and equipment.
- Acidic water for use in various medical technologies and equipment.
- Water purified from bacteria and microorganisms.

The installations can also be used for electrochemical disinfection of wastewater from laboratories and operating rooms in hospitals and research centers.

List of references, patent and license information

United States Patent Application **20130173180**
Kind Code **A1**
July 4, 2013

DETERMINATION OF ATTRIBUTES OF LIQUID SUBSTANCES

Abstract

A monitoring unit (100) that determines parameters (p1, p2) of an attribute (P) of a liquid substance flowing (F) through a dielectric conduit (110) includes plural coil members (121, 122) encircling the dielectric conduit (110) that subjects a flow of the liquid substance to plural different electromagnetic fields (B(f)), and under influence thereof measuring circuitry registers corresponding impedance measures (z(f)) of the liquid substance. A processor (130) derives the parameters (p1, p2) of the attribute (P) based on the registered impedance measures (z(f)).

United States Patent Application **20130178721**
Kind Code **A1**
July 11, 2013

VIVO DETERMINATION OF ACIDITY LEVELS

Abstract

A bolus for use in a ruminant animal's reticulum includes a cavity (100) configured to receive ruminal fluids present in the stomach. The cavity has walls (110) of a dielectric material and is encircled by a coil member (120), which is configured to subject the ruminal fluids to an electro-magnetic field. A Sensor element (310) measures the electromag-netic field's influence on the ruminal fluids and thus register an electromagnetic property representative of an acidity level of said fluids. A transmitter (410) transmits a wireless output signal (SD) reflecting the acidity measure.

United States Patent **8,694,091**
April 8, 2014

In vivo determination of acidity levels

Abstract

A bolus for use in a ruminant animal's reticulum includes a cavity (100) configured to receive ruminal fluids present in the stomach. The cavity has walls (110) of a dielectric material and is encircled by a coil member (120), which is configured to subject the ruminal fluids to an electro-magnetic field. A Sensor element (310) measures the electromagnetic field's influence on the ruminal fluids and thus register an electromagnetic property representative of an acidity level of said fluids. A transmitter (410) transmits a wireless output signal (SD) reflecting the acidity measure.

United States Patent **9,316,605**
April 19, 2016

Determination of attributes of liquid substances

Abstract

A monitoring unit (100) that determines parameters (p1, p2) of an attribute (P) of a liquid substance flowing (F) through a dielectric conduit (110) includes plural coil members (121, 122) encircling the dielectric conduit (110) that subjects a flow of the liquid substance to plural different electromagnetic fields (B(f)), and under influence thereof measuring circuitry registers corresponding impedance measures (z(f)) of the liquid substance. A processor (130) derives the parameters (p1, p2) of the attribute (P) based on the registered impedance measures (z(f)).

United States Patent **6,188,151**
February 13, 2001

Magnet assembly with reciprocating core member and associated method of operation

Abstract

An electromagnetic assembly includes a casing, a solenoid disposed inside the casing, a stationary magnetic core, and a movable magnetic core. The stationary magnetic core is disposed at least partially inside the solenoid and is fixed relative to the solenoid and the casing, while the movable magnetic core is disposed for reciprocation partially inside the solenoid along an axis. The stationary magnetic core, the movable magnetic core, the solenoid, and the casing have rectangular or square cross-sections in planes oriented essentially perpendicularly to the axis.

United States Patent Application	**20120040166**
Kind Code	**A1**
	February 16, 2012

Composite Material, Method of Manufacturing and Device for Moldable Calibration

Abstract

Composite materials and methods and systems for their manufacture are provided. According to one aspect, a composite material includes a collection of molded together multilayer capsules, each capsule originally formed of a core and shell. The shell, after a plastic deformation process, forms a pseudo-porous structure, with pores locations containing the capsule cores. The cores are made of a material, e.g., synthetic diamond, which is harder than the external shell, which can be formed of, e.g., a ductile metal such as copper. The composite material has high thermal and/or electrical conductivity and/or dissipation.

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